

SANS-USANS

Investigation of Magnetic Nanoparticles Chaining in Polymer Epoxy Nanocomposites



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Overview

- Background
- Synthesis
- Characterization Techniques
- Results
- Conclusions



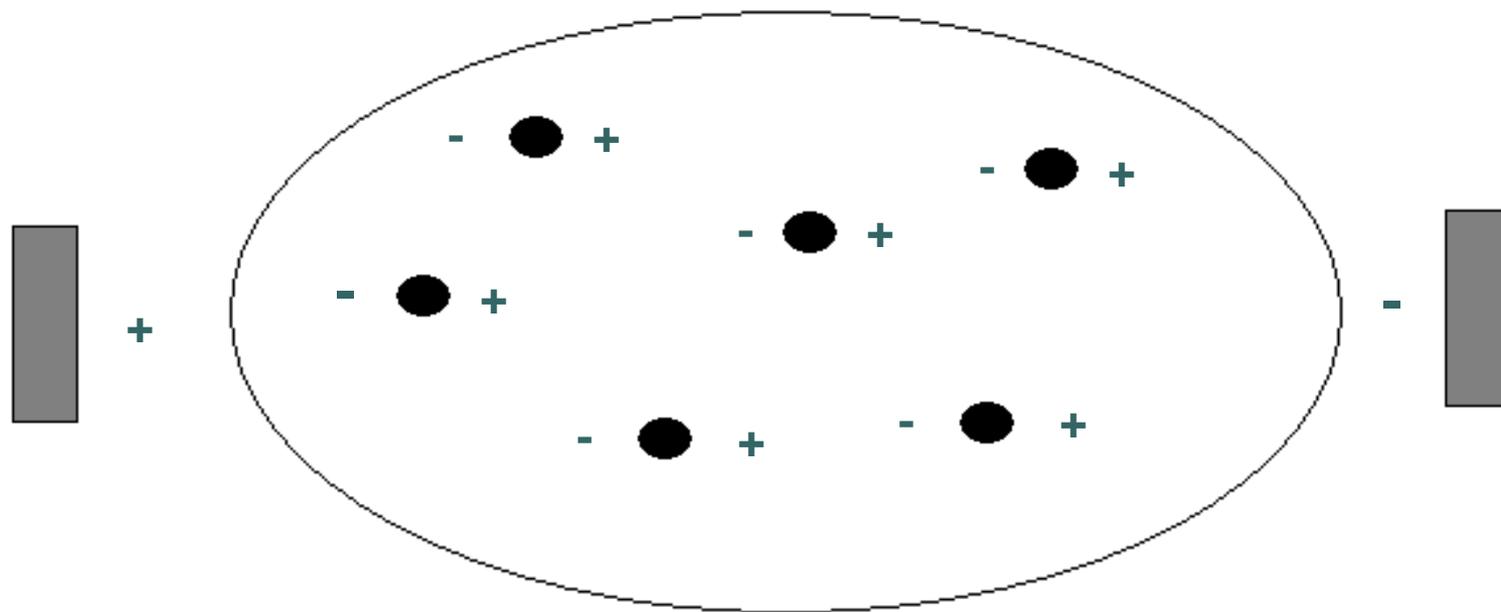
Magnetic Nanoparticles in Ferrofluids

- used with DC magnetic fields to shape and cure MNP loaded polymer epoxies
- MNPs form rigid chains that depend upon the magnetic field configuration
- Application: Bone tissue scaffolding

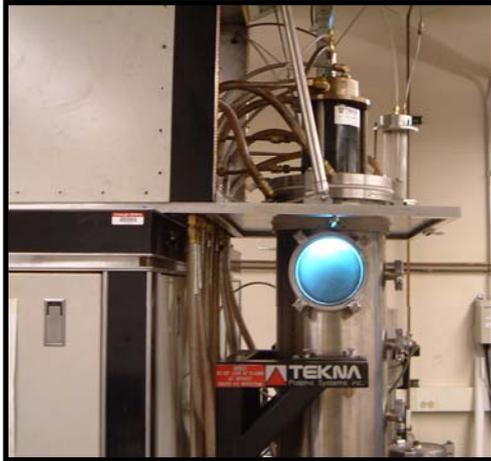




Chain Formation



Synthesis



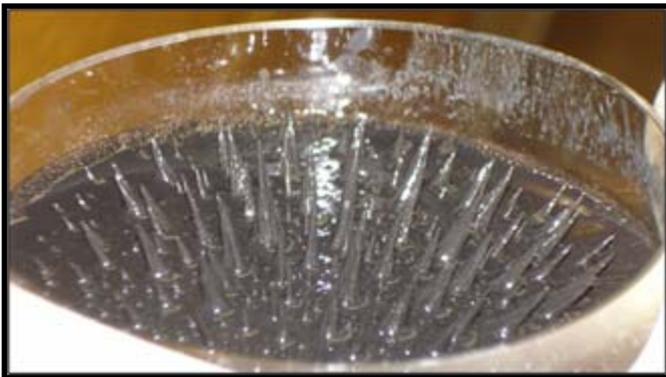
Plasma torch synthesis



Cryo-milling

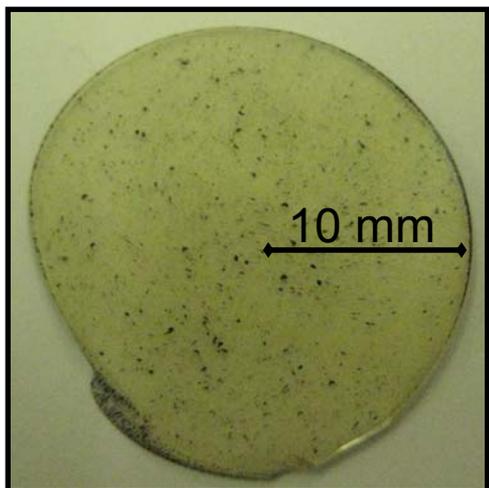


Ultrasonification

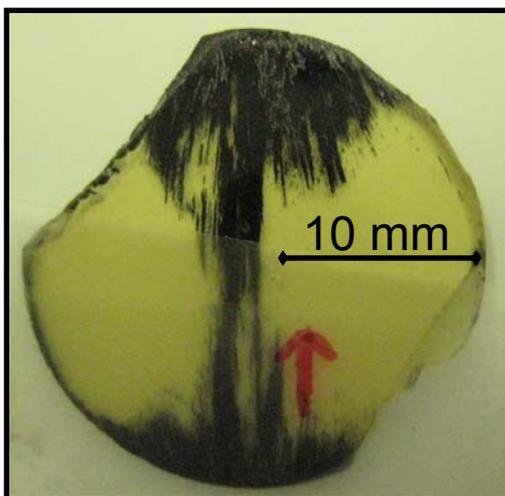


Ferrofluid

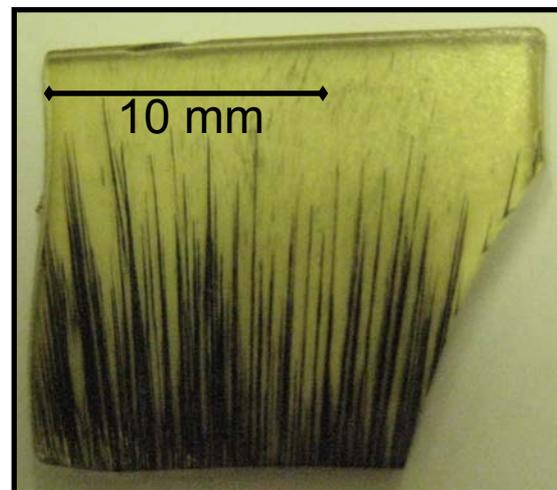
Samples



0.5wt% CM random



1.0wt% CM sides



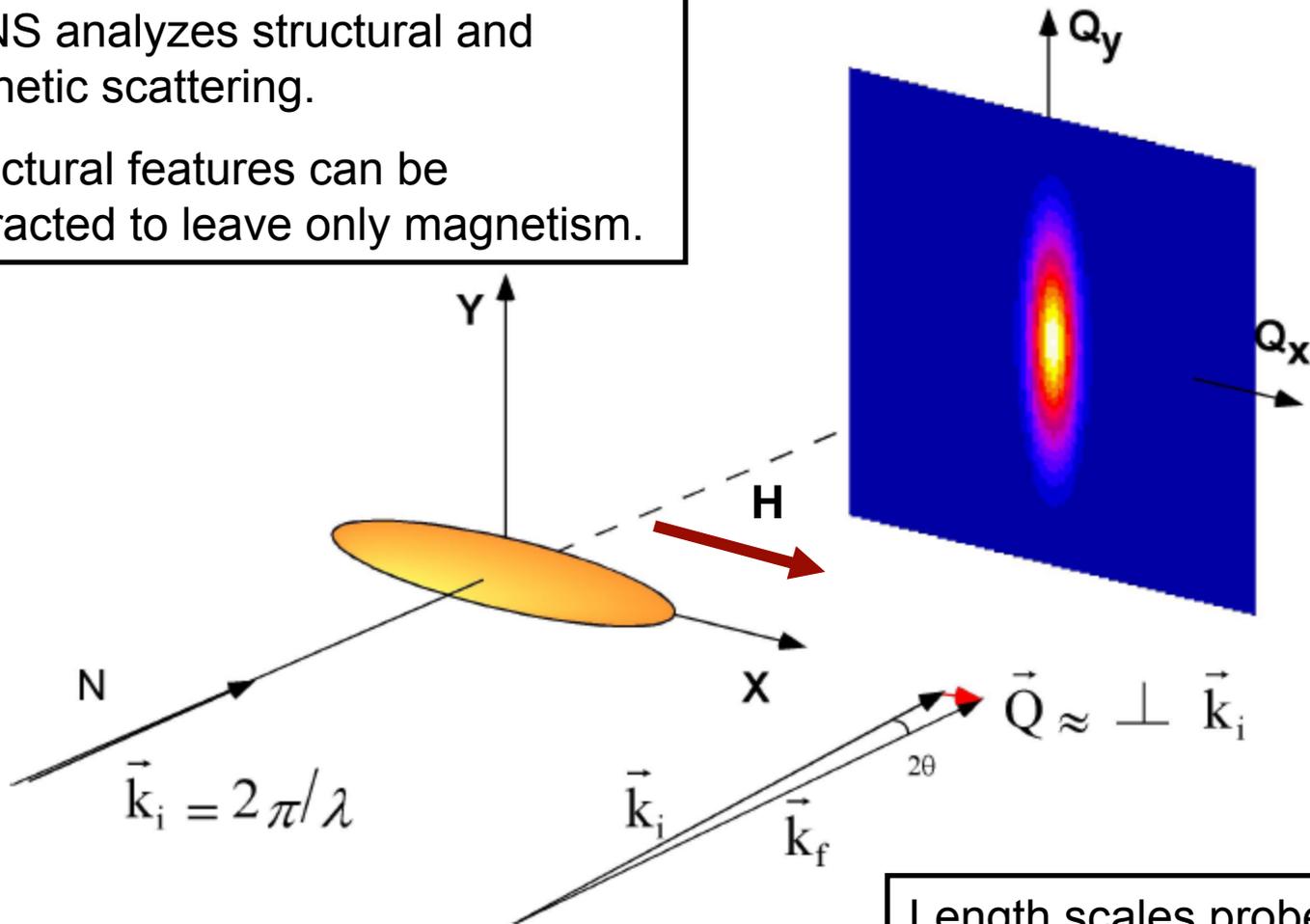
0.5wt% CM bottom



3.0wt% PT bottom

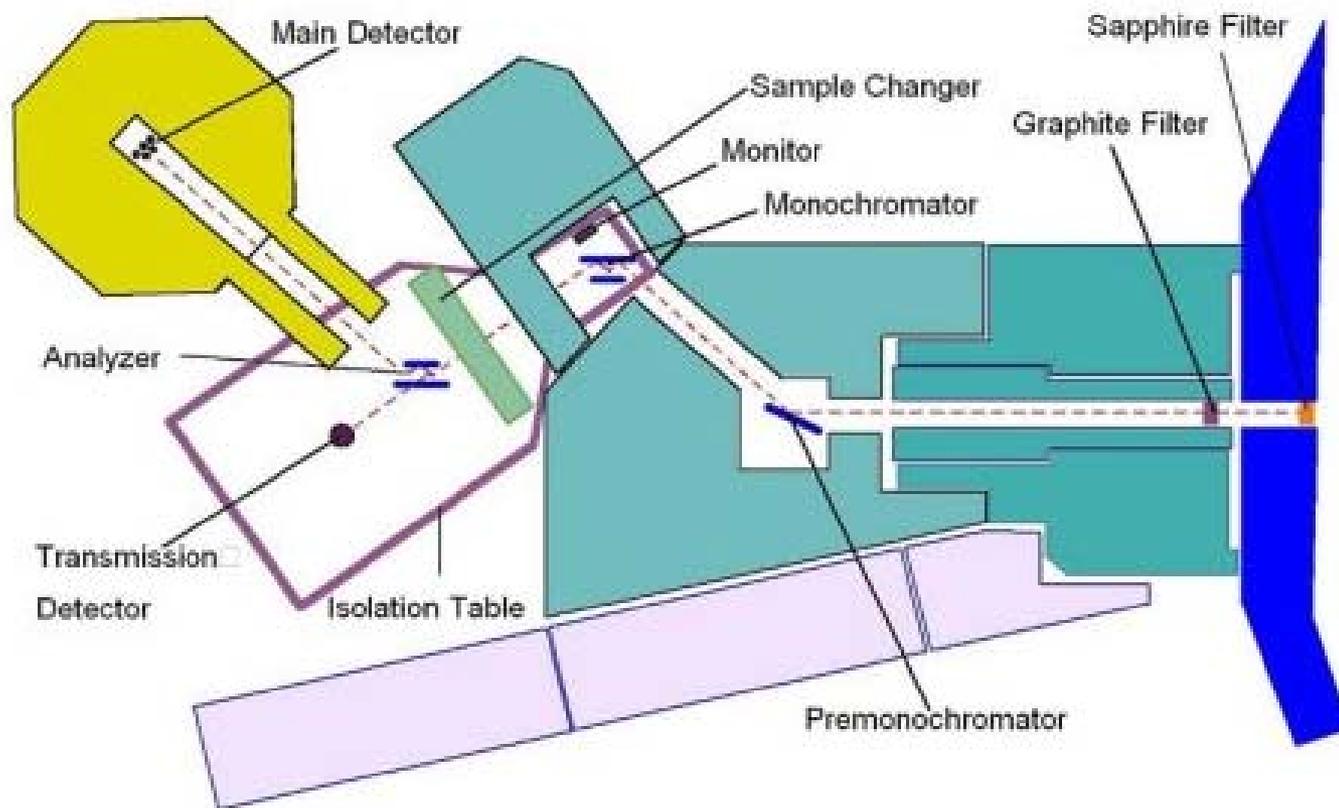
Small Angle Neutron Scattering (SANS)

- SANS analyzes structural and magnetic scattering.
- Structural features can be subtracted to leave only magnetism.



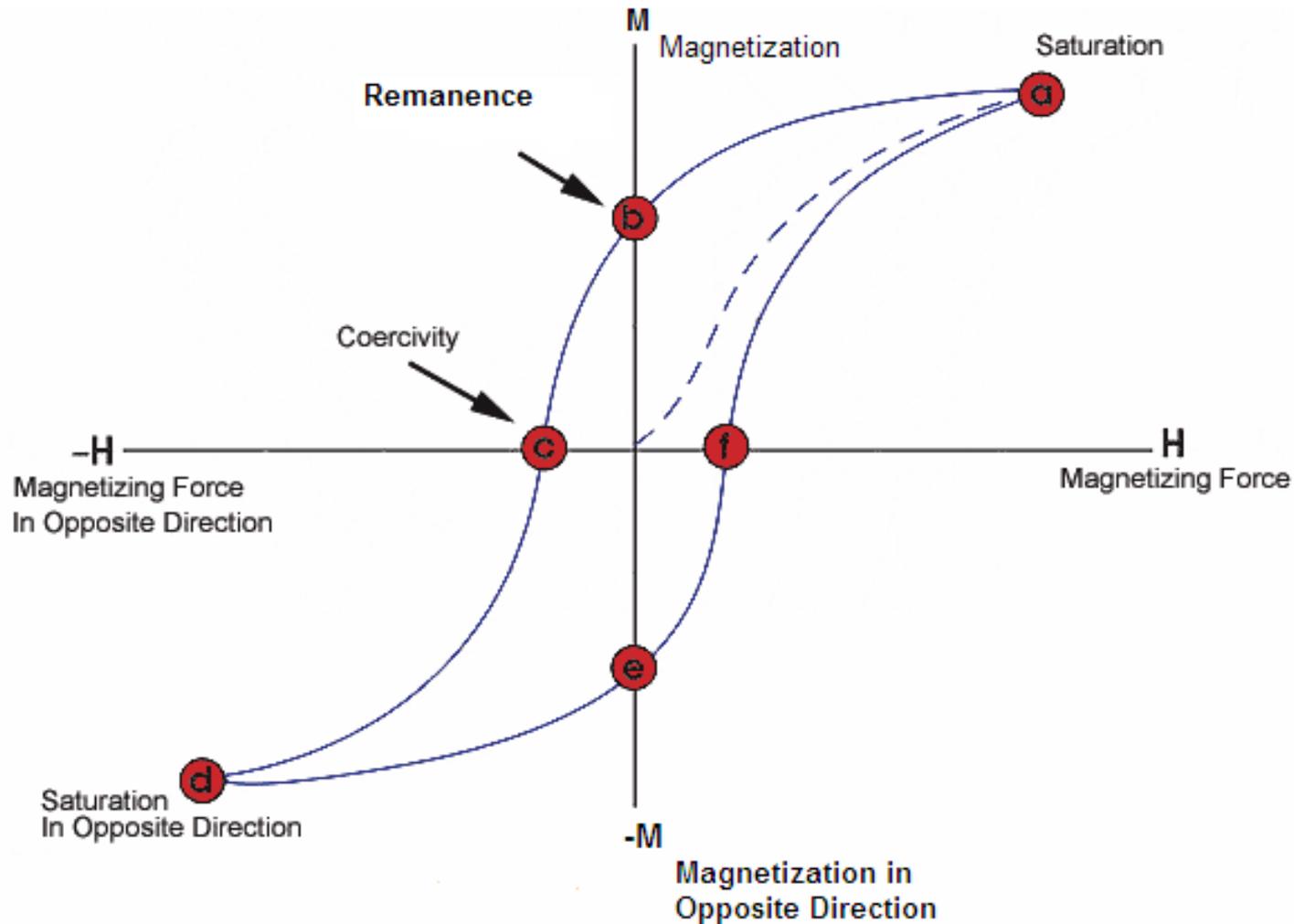
Length scales probed: 10-500nm

Ultra Small Angle Neutron Scattering (USANS)



Length scales probed: 100 to 10000 nm

Superconducting Quantum Interference Device (SQUID)



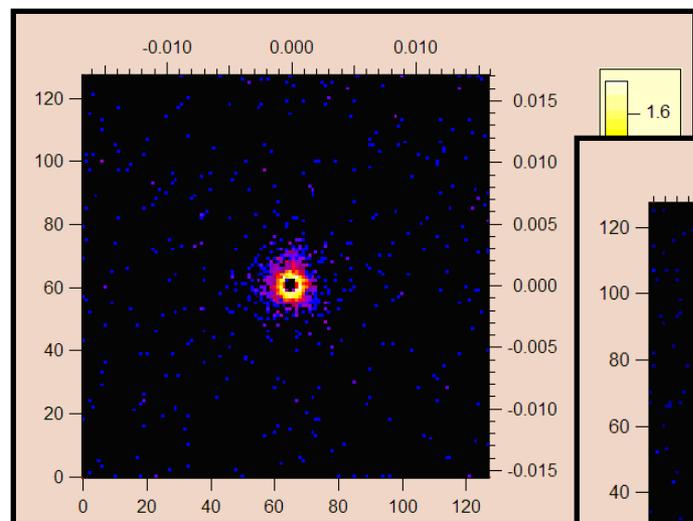
A decorative graphic consisting of three circles in shades of teal and grey, followed by a vertical line.

Results

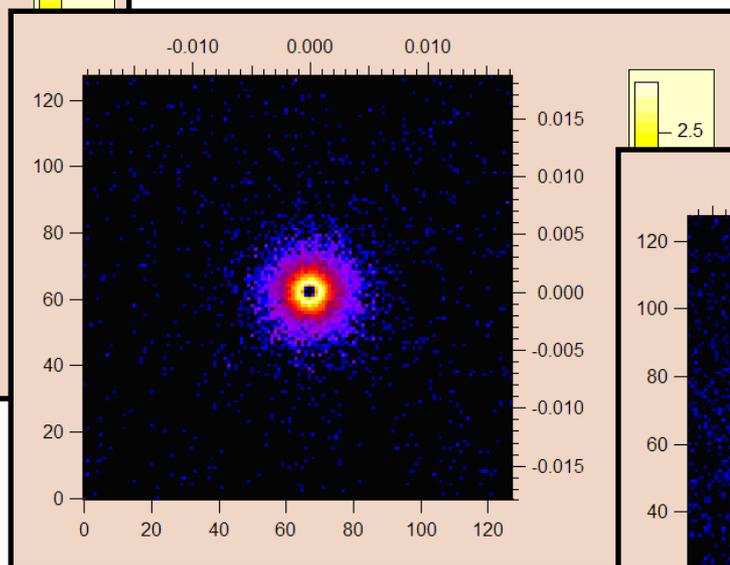
- Asymmetry in MNP Chains
- SQUID Magnetometry
- Field Dependence



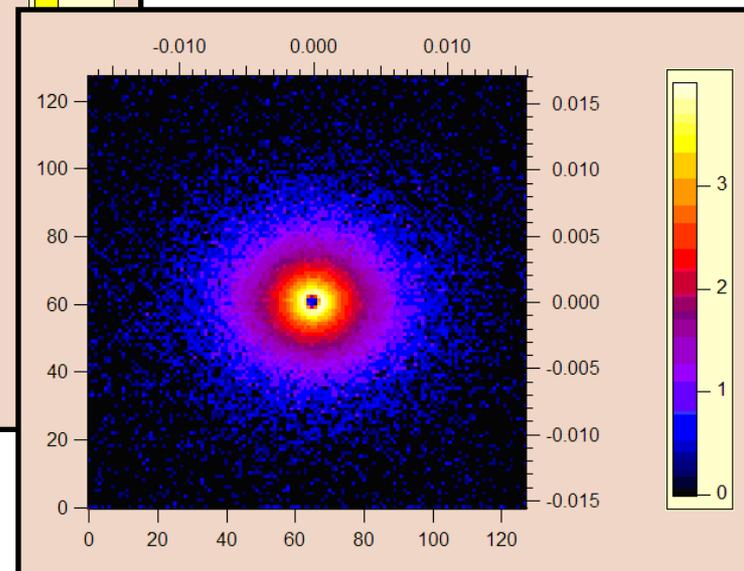
2D SANS



Blank Epoxy



0.5wt% CM Random

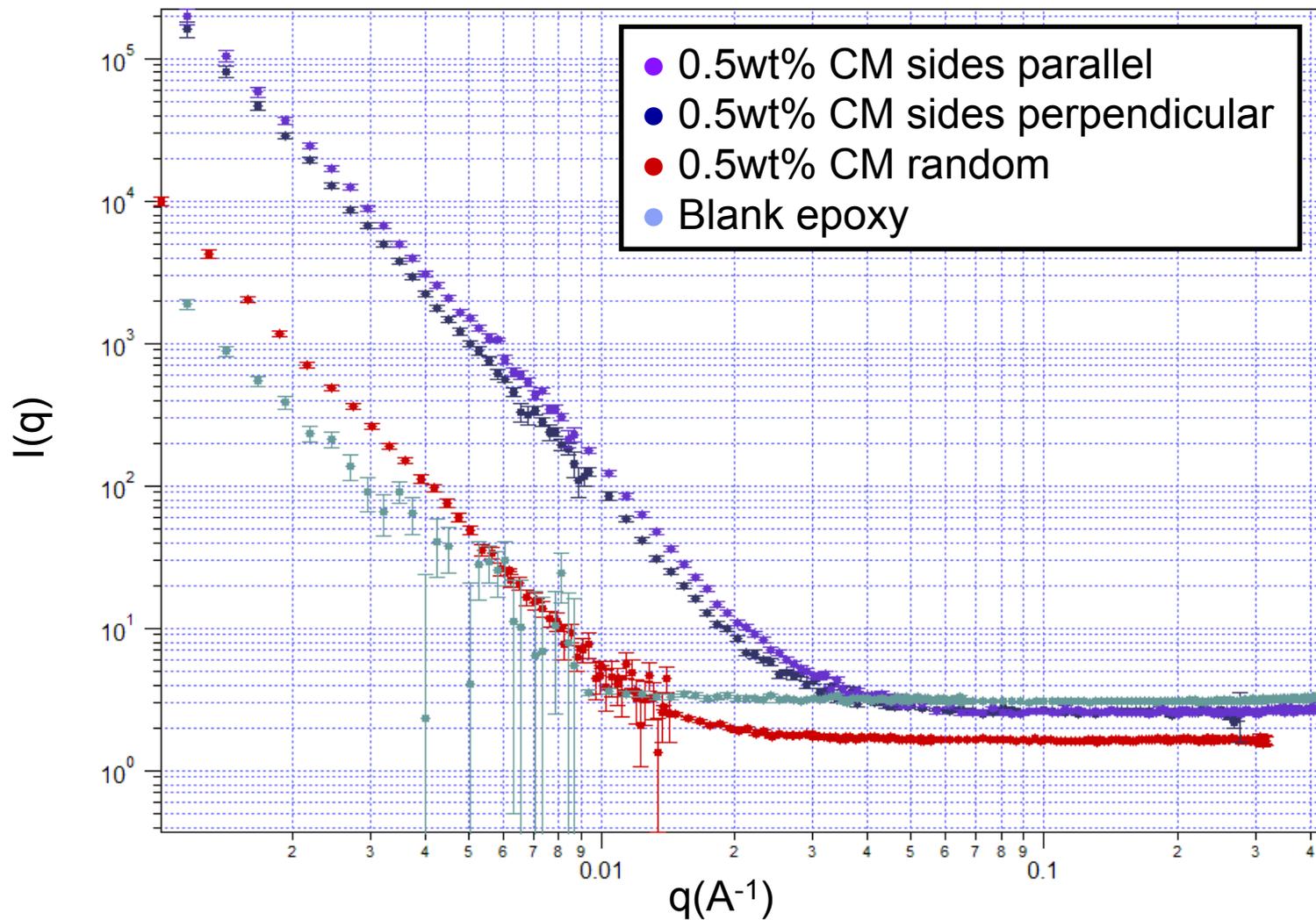


0.5wt% CM sides

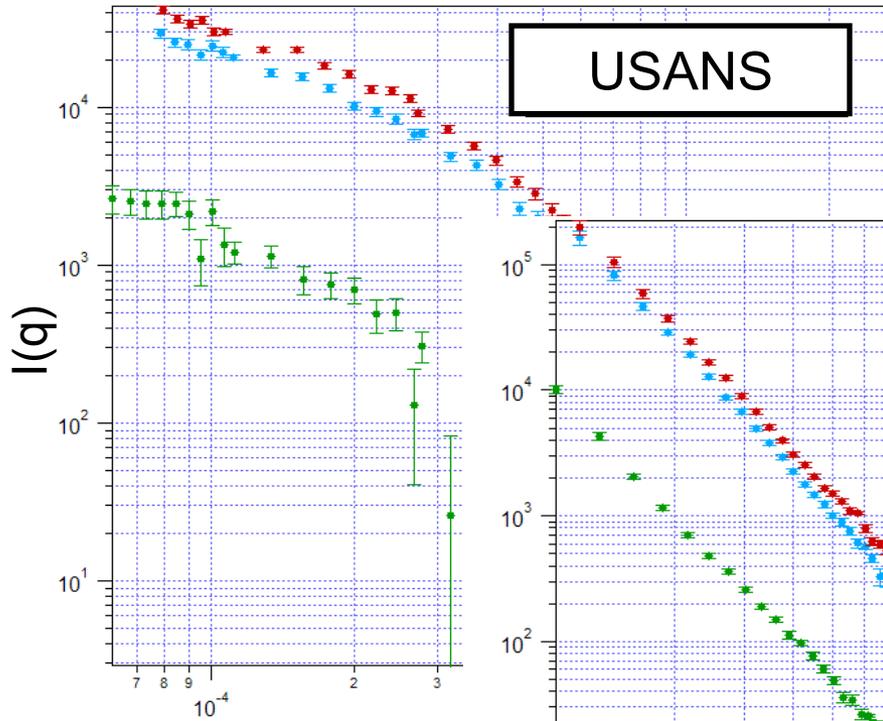
Low Q data



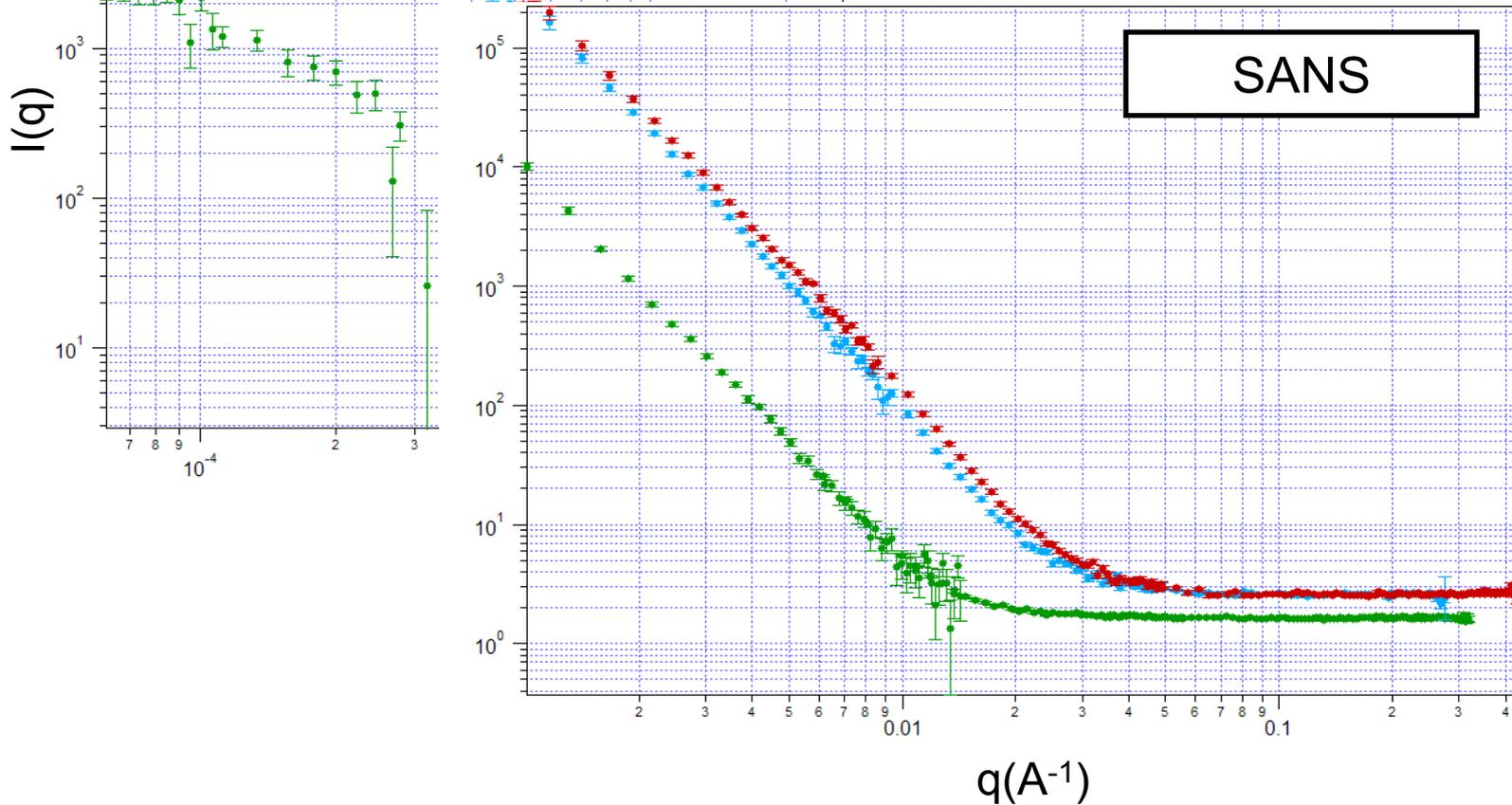
SANS



USANS

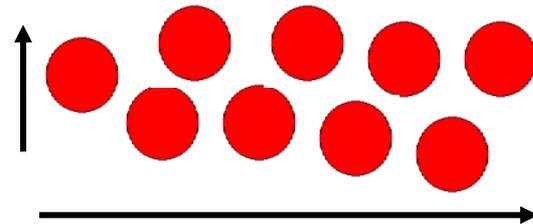


- 0.5wt% CM sides perpendicular
- 0.5wt% CM sides parallel
- 0.5wt% CM random

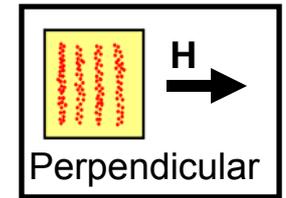
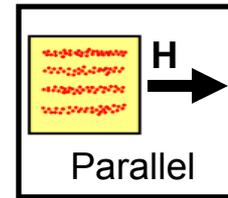


Structural Asymmetry of Chains

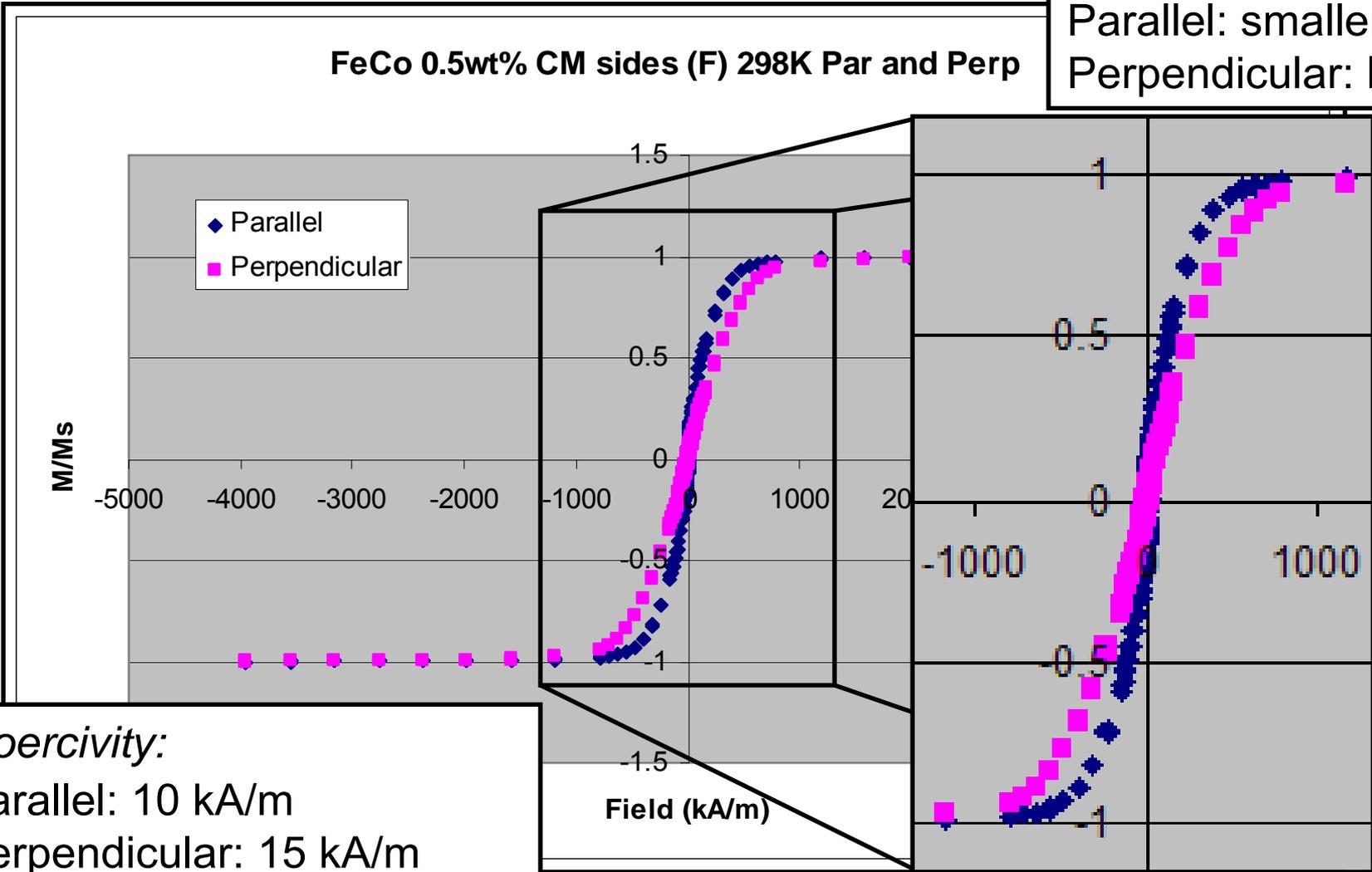
- Low Q scattering
 - Large structure clustering
- Long range chain structure
 - perpendicular: shorter clusters
 - parallel: longer clusters
- Long length scales along both directions of chain



Magnetometry



Saturation:
 Parallel: smaller
 Perpendicular: larger



Coercivity:
 Parallel: 10 kA/m
 Perpendicular: 15 kA/m

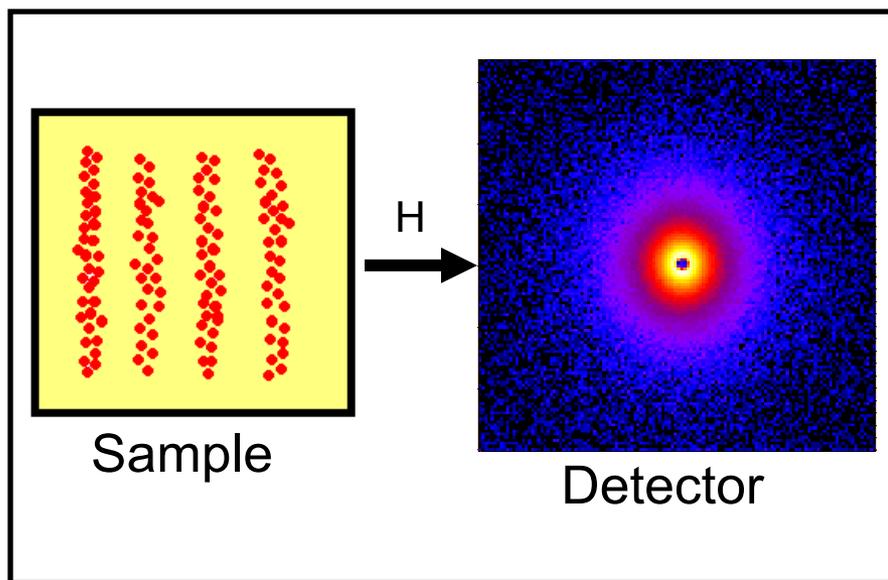
Magnetometry

- Coercivity difference between parallel and perpendicular directions
- Position of magnetic moments in MNPs



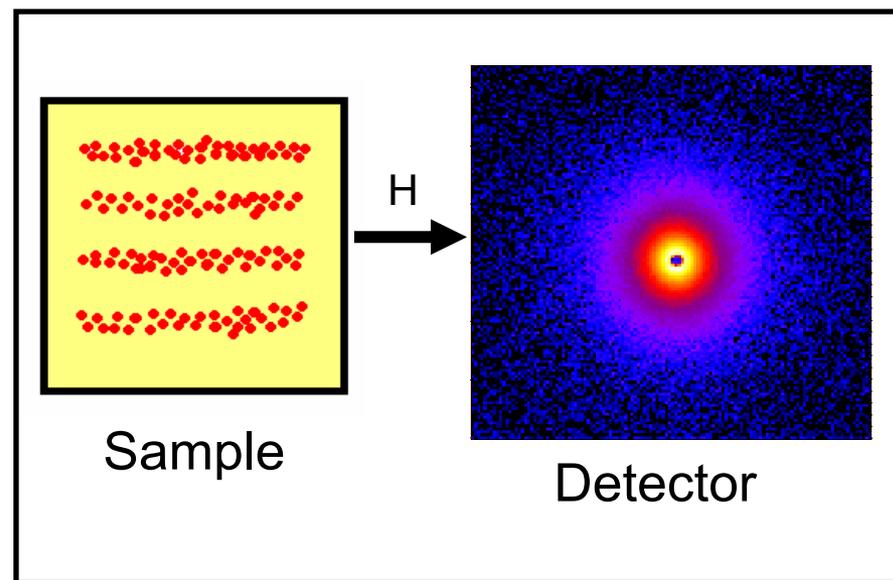
Field Dependence

Perpendicular



Across width of chains

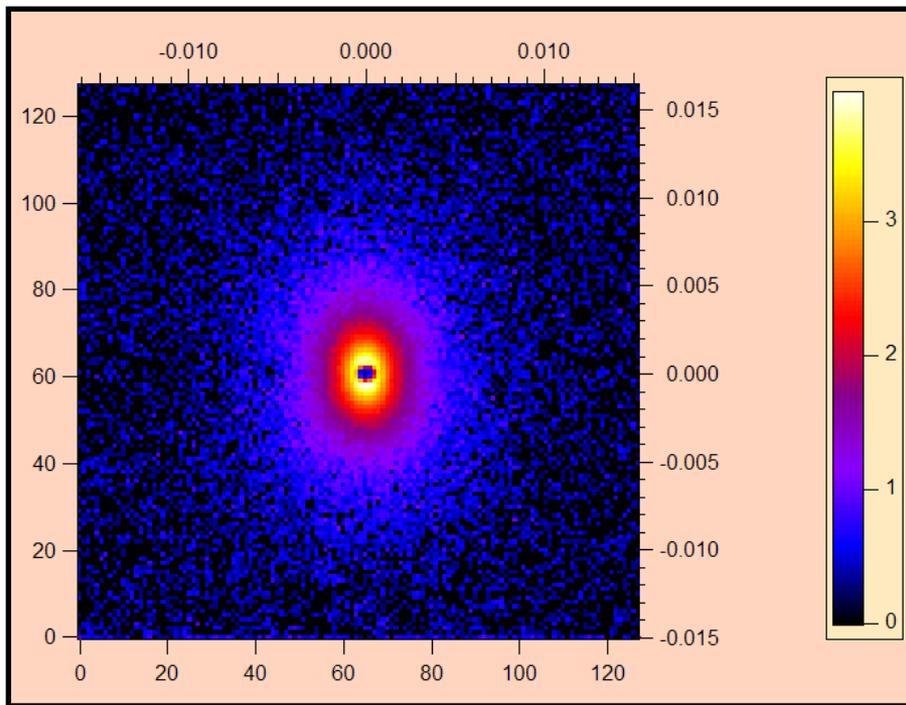
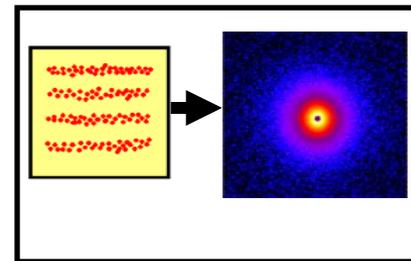
Parallel



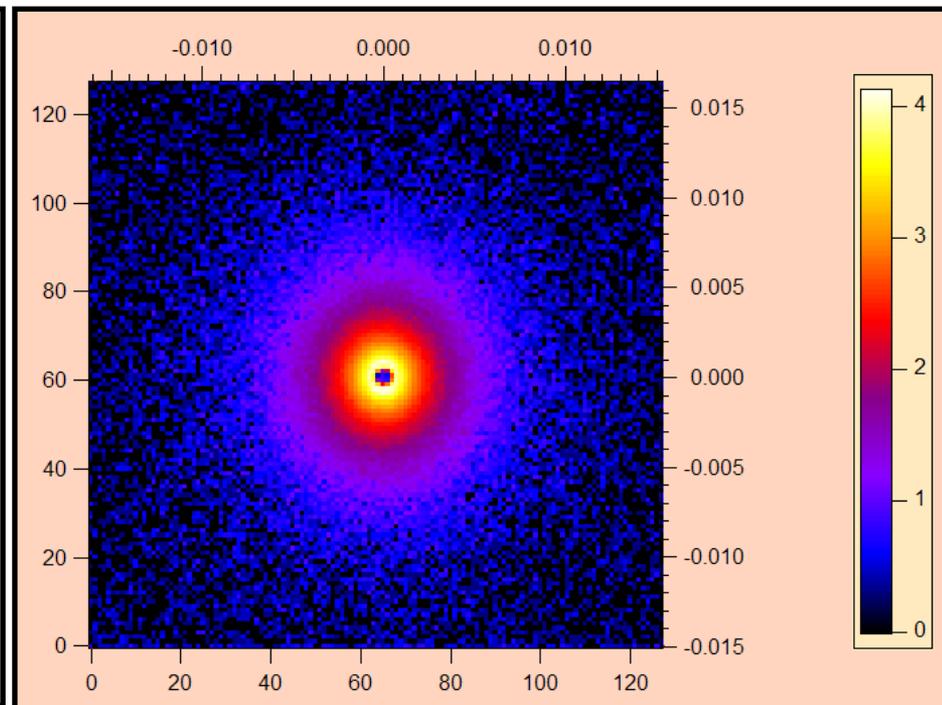
Along length of chains

Field Dependence

0.5wt% CM Chained Parallel



1106 kA/m



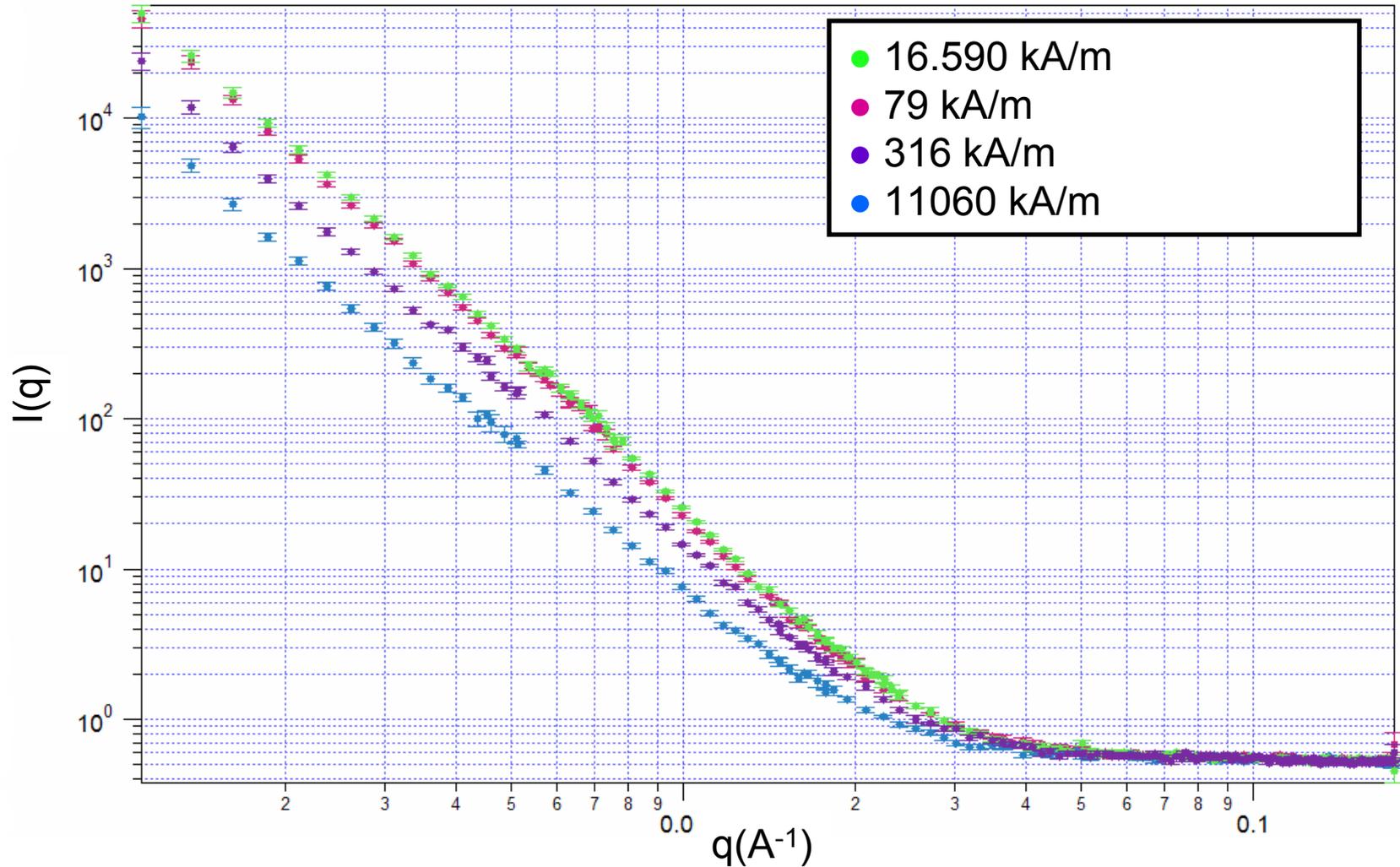
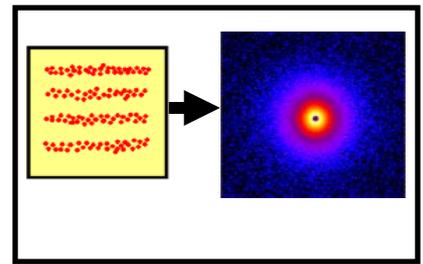
16.590 kA/m

Magnetic Selection Rule:

No scattering parallel to wave vector Q

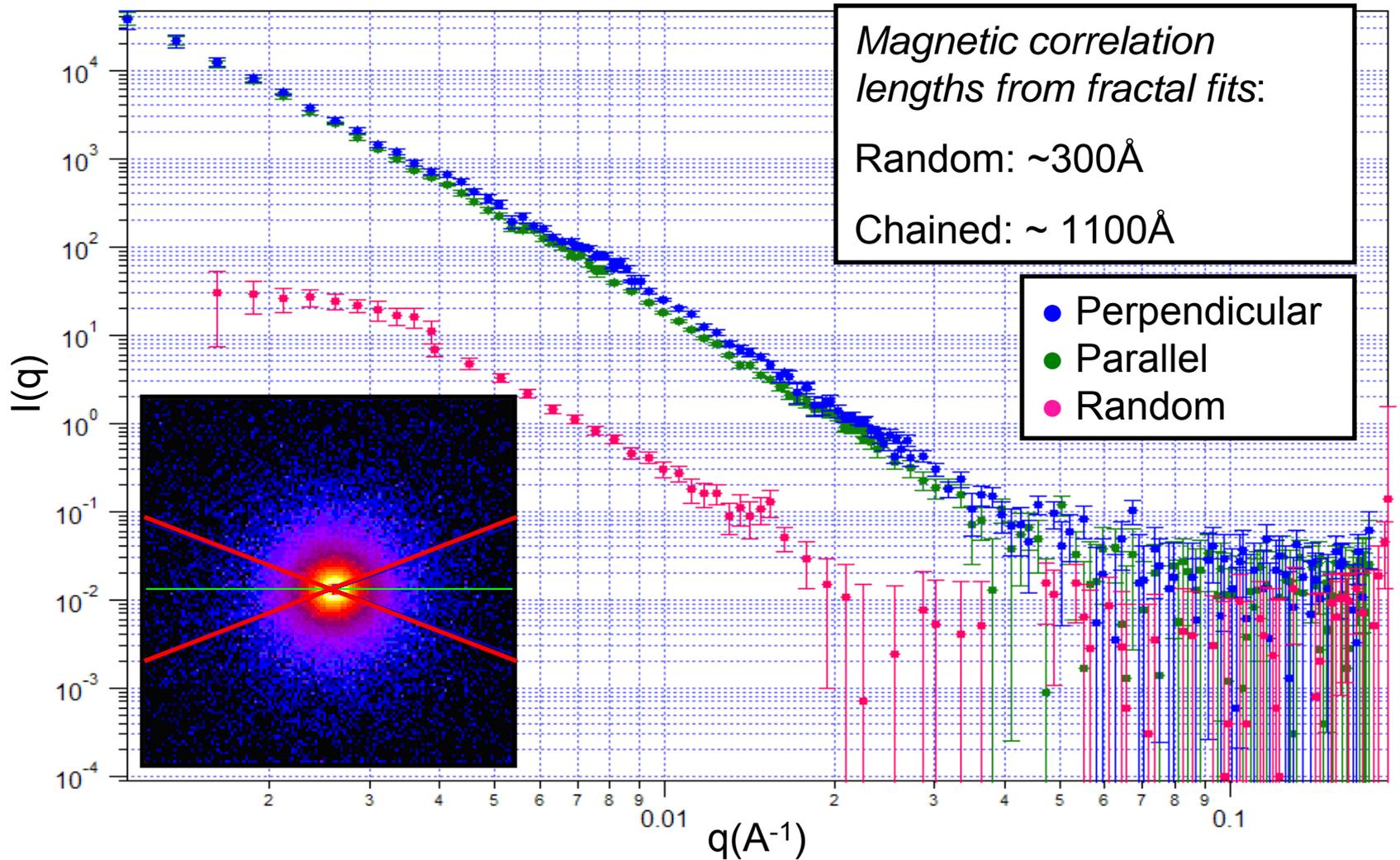
Field Dependence

0.5wt% CM Chained Parallel

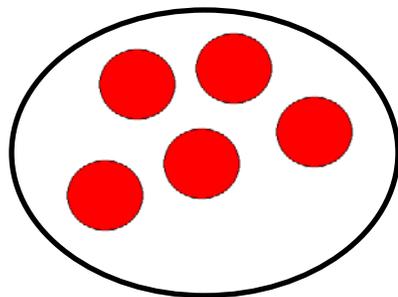
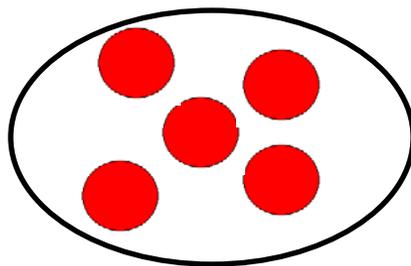
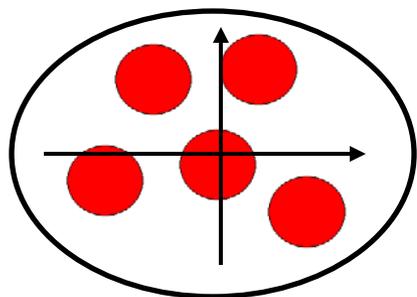
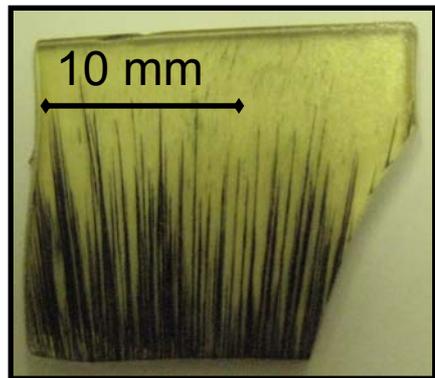


Field Dependence

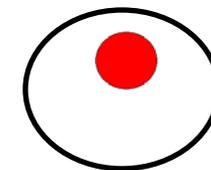
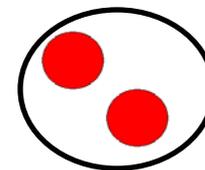
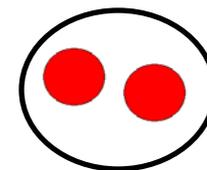
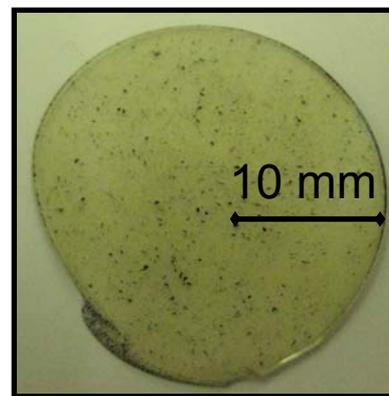
0.5wt% CM samples 16.590 kA/m
w/ high field subtracted



Remanent Magnetic State



Chained: $\sim 1100\text{\AA}$



Random: $\sim 300\text{\AA}$

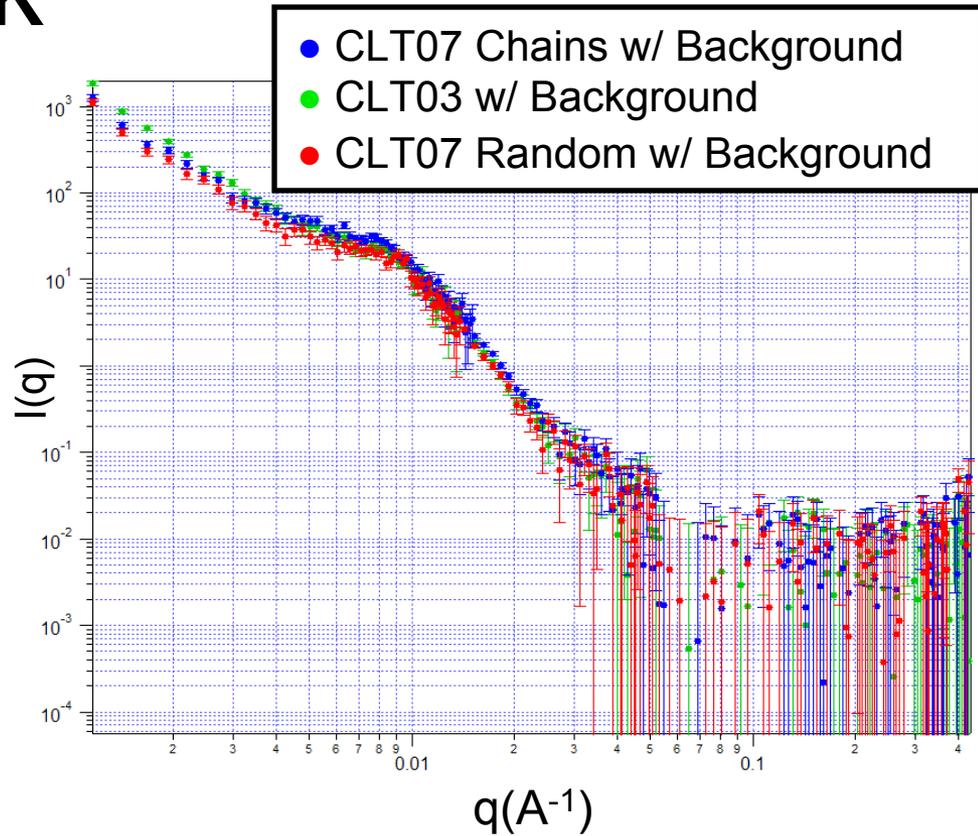
Conclusions

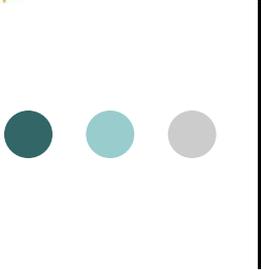
- Epoxy stabilizes MNPs
- Clusters forming clusters
- Random vs. Chained samples:

	<i>Random</i>	<i>Chained</i>
<i>Structural</i>	Long range > 1×10^4 Å	Long range > 1×10^4 Å
<i>Magnetic</i>	Short range ~300 Å	Long range ~1100 Å

Future Work

- Tape
- CLT samples
- Ferrogels





Acknowledgements

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